Module 4.1 – Natural Laws - Lesson Plan

Long-term Learning Goals and Students' Learning Targets:

Effects of Gravity and Energy of Motion

The student uses critical thinking, decision-making, and problem solving skills to recognize the effect of gravity and energy of motion on friction and traction; the forces of an impact; factors that affect a vehicle while in a curve; how tire condition affects traction; factors affecting braking distance; the effect of energy of motion on vehicles of different weights; the effect of forces when mixed sized vehicles collide; and how altering a vehicle can affect vehicle balance and traction.

The student is expected to:

- define gravity and energy of motion;
- describe the effect gravity and energy of motion have on friction and traction;
- describe the effect of speed on energy of motion;
- describe the forces of an impact;
- describe the impact of tire condition and air pressure on traction;
- describe the forces while in a curve;
- describe the factors that affect braking distance;
- describe the consequences of vehicle modifications on vehicle balance and traction; and
- describe the forces of energy on vehicles of different weights and size.

Maintaining Vehicle Balance

The student understands how to identify maximum vehicle load; examines the changes in vehicle balance when braking and steering; recognizes how seating, hand and feet position is used to maintain vehicle balance; recognizes the effects of vehicle load on vehicle balance; recognizes the effect of aggressive steering, braking, and acceleration inputs on the balance of a vehicle, and explains how to use vision control, motion control, and steering control to maintain vehicle balance.

The student is expected to:

- describe how to determine a vehicle's maximum load;
- describe the cause and effect of vehicle load changes (balance) from side to side, front to rear, and rear to front;
- describe the effect of vehicle load on vehicle balance;
- describe and demonstrate proper seating position for vehicle balance and control;
- describe and demonstrate proper positioning of the hands and steering techniques to maintain vehicle balance and control;
- describe how aggressive steering, braking, and acceleration affects vehicle balance and control;
- describe and demonstrate foot positions to maintain vehicle balance and control; and
- describe and demonstrate acceleration and braking techniques to maintain vehicle balance and control.

Maintaining Traction Control

The student recognizes vehicle imbalance and evaluates vision control, motion control and steering control to prevent loss of vehicle control. The student investigates vehicle braking systems, traction and steering control systems, and stability control systems to maintain vehicle control.

The student is expected to:

- describe traction loss and effect to both the front and rear wheels;
- list conditions that can create traction loss and vehicle imbalance;
- describe how traction and vehicle balance are affected by steering, acceleration, deceleration and roadway surfaces;
- identify the difference between two-wheel and four-wheel drive systems.
- explain the function and advantages of two- and four-wheel anti-lock braking (ABS) systems;
- identify vehicle braking systems and the proper braking techniques used for those systems; and
- explain the purpose of enhanced (variable-assist) steering, stability control and traction control systems.

Materials Needed:

1. **Module 4.1 PowerPoint Presentation**
2. **Module 4.1 Fact and Work Sheets (printed for each student)**
3. **Module 4.1 Teacher Commentary (printed out)**
4. **Paper**

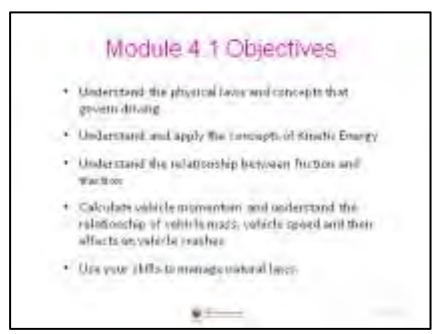
TEACHER COMMENTARY

The following are questions you can ask during the presentation to engage students and have them develop key concepts related to Effective Vision Control.

Representation of the module slides are provided to allow you to connect the materials, data, and questions with the presentation.

Slides 1 and 2 - Natural Laws – Objectives

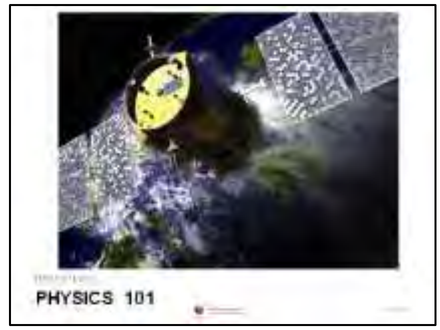
- **Understand the physical laws and concepts that govern driving**
- **Understand and apply the concepts of Kinetic Energy**
- **Understand the relationship between friction and traction**
- **Calculate vehicle momentum and understand the relationship of vehicle mass, vehicle speed and their effects on vehicle crashes**
- **Use your skills to manage natural laws**

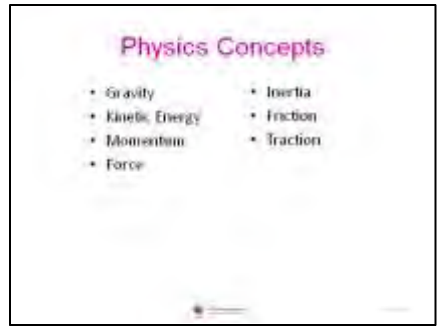


Slides 3 and 4 – Physics Concepts

NASA Infrared Pathfinder Satellite Observations. CALIPSO is a mission of the United States and France. Activities such as driving cars and trucks, burning coal and oil, and manufacturing chemicals release gases and small particles known as aerosols into the atmosphere. Forest fires and wind-blown desert dust also produce aerosols. CALIPSO uses Lidar to study the aerosols and thin clouds. LIDAR is a short name for Light Detection and Ranging. It can see things that are invisible to radar. http://www.nasa.gov/mission_pages/calipso/main/index.html.

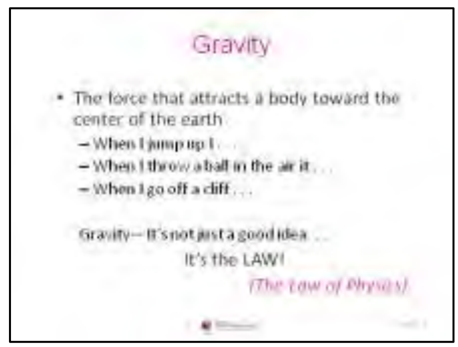
LIDAR is used in Google's self-driving car project with 64 infrared lasers spinning to create a 3-D ongoing 360° model of traffic and the roadway.





Slide 5 - Gravity

Ask the questions as they appear and solicit a response from the students. Gravity is one law that can't be broken. It will always require obedience to the law.



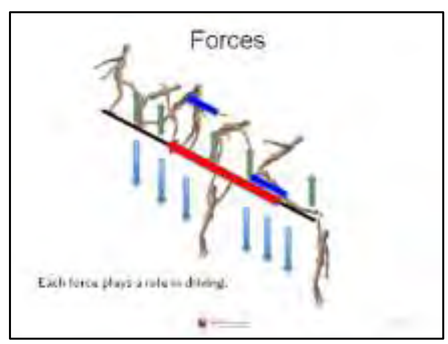
Slide 6 - Forces

Force of gravity — pulls down on the vehicle helping the car maintain contact with the roadway.

Force of the board pushing upward — keeps the car from falling. This force creates a balance between it and the downward pull of gravity.

Force of Friction keeping them from sliding — the key element of traction. Without friction we would not be able to steer, accelerate or brake.

Force of grasp by others holding them from sliding — this is more symbolic with the way safety belts hold us in place when we are involved in a crash or extremely hard braking.



Slide 7 – Hills and Gravity

How would you describe what's happening with his feet as he runs over the crest of the hill and then at the bottom of the hill? What do you think will happen if you are driving over a hill? What happens at the bottom of the hill?

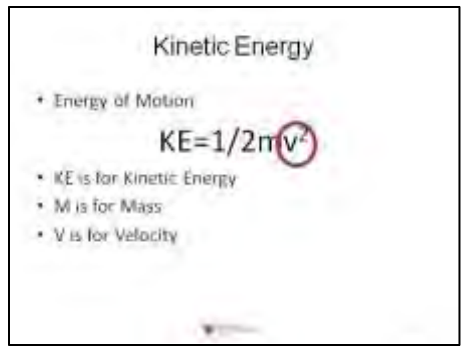
The force of gravity is at work the entire time. If you look at the top of the hill the runners actually leave the ground. At the bottom of the hill the runners feel the ground pushing up and gravity pulling down to the point where one of the runners nearly falls.

Slide 8 – Kinetic Energy

The equation makes it clear that when I double my speed from 20 to 40 mph I quadruple my KE. Remember that speed is squared so going 20 mph I have 400 units of energy times half the mass of the vehicle. If I go 40 mph I have 1600 units of energy times half the mass of the vehicle effectively quadrupling the KE.

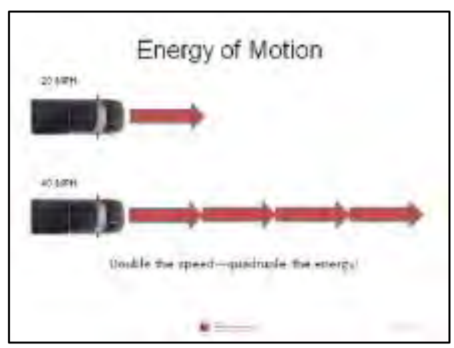
That affects a lot of things:

- **Energy of the vehicle and occupants in a crash**
- **Energy needed to stop or slow a vehicle**
- **Stopping distance**
- **Cornering**
-



Slide 9 – Energy of Motion

Remember the Kinetic Energy equation where velocity is squared. Therefore the 6000-pound vehicle has 1.2 million units of energy at 20mph. Doubling the speed of the vehicle gives the truck 8.2 million units of energy.



Slide 10 – Stopping Distance

Speed and stopping distance. The faster you go the more distance it takes to stop.

- **60 kilometers per hour is equal to 36mph.**
- **25 meters is equivalent to 77 feet.**
- **Adding 10 kilometers per hour is adding 6 mph so 70 KPH is equal to 42 miles per hour.**

This is a good representation of the dynamics of speed and the effect it has on stopping distance.

Slide 11 – Stopping Distance

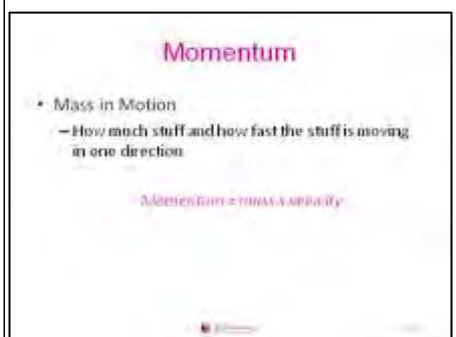
Using what we know from the Kinetic Energy equation, which of these two vehicles traveling at the same speed will take longer to stop?

Which one has the most kinetic energy if they were going the same speed? The 80,000-pound truck or the 4000-pound SUV?

Put the answer in terms of the Kinetic Energy equation.

Slides 12 and 13 – Momentum

Momentum adds the directional component. It is the mathematical description of how much mass is moving at what speed and includes the component of direction.

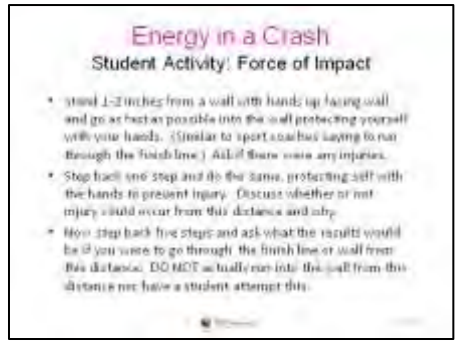


Doing the math the 5000-pound SUV has the most momentum. The formula of p=mv translates into 5000 x 20mph equals 100.000 units of momentum. The 200 pound cyclist at the same speed has 4000 units of momentum. Put simply, the SUV has 25 times the momentum of the cyclist and that helps explain why car/cyclist crashes are so devastating to cyclists. That all translates into the energy in a crash.

Slide 14 – Energy in a Crash – Study Activity

Speed and impact student activity: This is a great way to spark a discussion about vehicle crashes involving speed and injuries with impact distance. It is also a great way to reinforce the riding down effects of seat belts when involved in a crash.

- **Stand 1-2 inches from a wall with hands up facing wall and go as fast as possible into the wall protecting yourself with your hands. (Similar to sport coaches saying to run through the finish line.) Ask if there were any injuries.**
- **Step back one step and do the same, protecting self with the hands to prevent injury. Discuss whether or not injury could occur from this distance and why.**
- **Now step back five steps and ask what the results would be if you were to go through the finish line or wall from this distance. DO NOT actually run into the wall from this distance nor have a student attempt this.**



Slide 15 – Check this road out

Lead the students in a discussion on this slide about how the road design and surface can contribute to a crash.

Slide 16 – Question about cause of crash

This is a great time to talk about forces and energy in a crash. It took a lot of energy to break this pole. It is a 25 in diameter high voltage power pole that is buried 8 feet in the ground. The pole next to it was installed after the crash to support the electrical wires. The next slide has a picture of the vehicle that hit the pole.

Questions you might want to ask:

1. **What kind of car caused this break?**
2. **How fast do you think it was going?**
3. **Is it possible that someone could have been killed or injured in this crash?**
4. **Could you survive a crash where your car caused the pole to break like this?**

Slide 17 – Answer …

This is a picture of a car involved in a crash in Oregon. The driver was a 17 year old high school student who was joy riding in his parents car by himself. He was driving 100 mph on a rain slicked hilly road when he lost control and slid passenger side into the pole.

Fortunately for him, he was wearing his safety belt and the airbags did deploy. He doesn't remember getting out of the car after the crash but remembers standing by the side of the car trying to figure out what happened.

Several things are certain. Speed and rain were a factor in the crash and inexperience contributed as well. Three fortunate things happened with this crash. The quality of the vehicle and its safety features, no one else was in the car, and he struck the pole on the opposite side of the driver's side.

The car literally broke in two at impact with the pole. The pole cost $25,000 to replace—let alone the cost of the car and the possible loss of life.

Slide 18 – That's Why Speed Kills!

This is a good time to lead a discussion on how speed affects the following:

- **Traction**
- **Vehicle dynamics**
- **Cornering**
- **Cresting hills**
- **Bottom of hills**

The increased energy changes the way the car handles and therefore makes it more difficult to control for the novice driver.

Slide 19 – Remember Vehicle Balance

This is a quick review of what the students have already learned so you don't have to spend a lot of time on this, but it is important to remind them how a car behaves on the 3 axis.

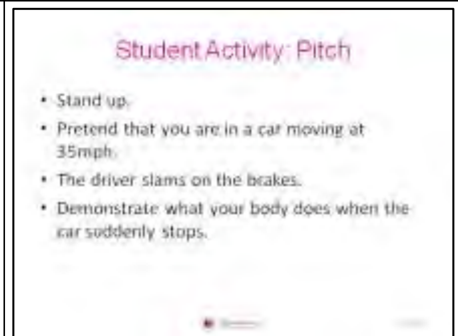
Working outside the natural laws will cause the car to rotate around the three different axes. This can be gentle or it can be quite out of control. Consider the following diagrams and do the student activities to recall how the car will move around these axes.

Slide 20 – Pitch

Pitch is caused by braking too hard or accelerating too rapidly.

Slide 21 – Student Activity: Pitch

Instructions for this activity are on the slide.



Slide 22 – Roll

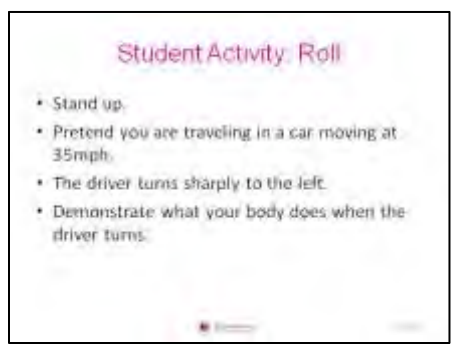
Roll is the movement of the car around an axis that runs from the front grill, through the car, to the trunk.

It is caused by turning too quickly at speed. The weight is transferred to the tires on the outside of the turn.

If the speed is increased and the force is sufficient the vehicle can roll completely over.

Slide 23 – Student Activity: Roll

Instructions for this activity are on the slide.
Remember to have them lean in the opposite direction.



Slide 24 – Yaw

Yaw is the movement around the axis that runs through the center of the car from the floor to the roof.

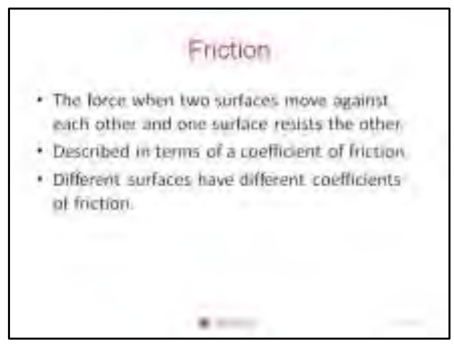
Movement can be as subtle as a slight side-to-side movement around the axis to a 180 or 360 degree spin.

Slide 25 – What is happening to this vehicle in balance terms?

Have the students describe what they see in terms of Pitch, Yaw, and Roll.

Slide 26 and 27 – Friction

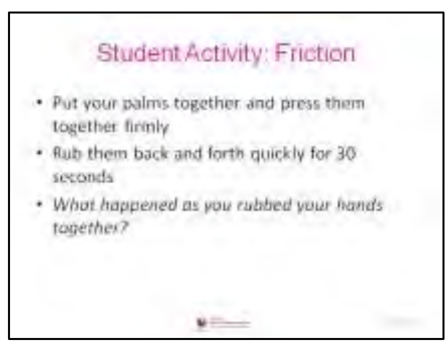
- **The force when two surfaces move against each other and one surface resists the other.**
- **Described in terms of a coefficient of friction.**
- **Different surfaces have different coefficients of friction.**



Slide 28 – Student Activity: Friction

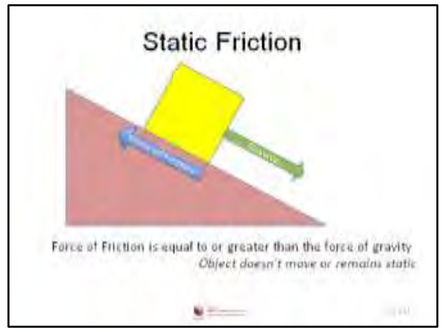
The purpose of this activity is to let the students discover friction. The heat is an indication that there is friction between the two surfaces. This translates into the concept of traction. Traction is the four tires making contact with the road and providing "grip" to hold the car on the road as we accelerate, stop, or turn.

If they press hard enough they will notice that their hands won't move. They will learn that when the force of friction is greater than the force to move their hands, nothing moves.



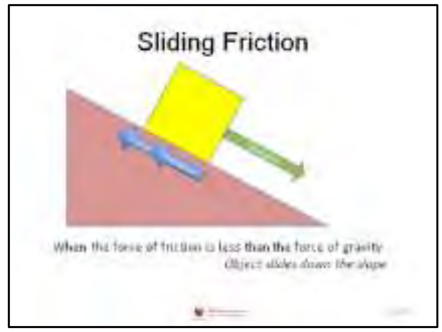
Slide 29 – Static Friction

Static friction is the friction that keeps the block from moving. Equal force is exerted on the box and slope, and is sufficient to overcome the downward force of gravity which would cause it to slide.



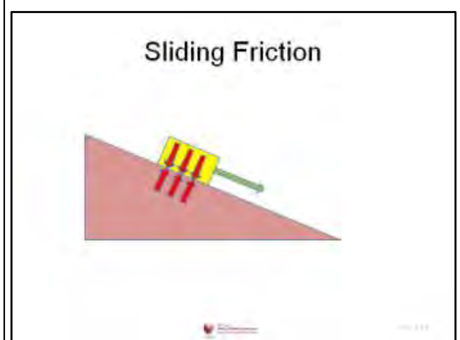
Slide 30 – Sliding Friction

When the force of friction is less than the force of gravity, the object will slide down the slope. The same is true on a flat, icy or snowy surface. It overcomes the force of friction and slides down the slope.



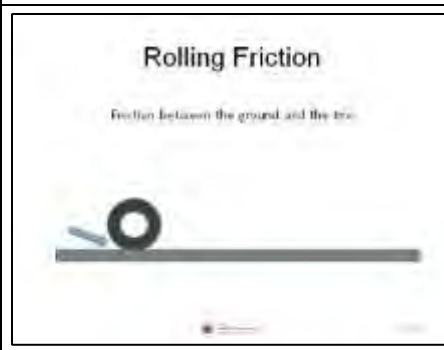
Slide 31 – Sliding Friction and Mass

Mass also plays a role in friction. The lighter the object, the more likely it will slide. Consider what happens to a pickup truck on a snowy day. The back end is very light and slips easily on the roadway. One thing to do is to add weight to the back end with sand bags, which increases the friction or traction with the road.
Going over the crest of a hill, like you saw in an earlier slide, creates the same effect. As you crest the hill the car loses some of the contact with the roadway and friction is reduced. If the driver crests a hill and also turns the wheel to steer through a curve, the friction of the tires and roadway is reduced.



Slide 32 – Rolling Friction

We rely on rolling friction to keep us on the road. However, the road opposes the motion of the tire when it rolls along the surface. Rolling friction occurs because tires flatten slightly during contact. The amount of friction increases the more the tire flattens or deforms. If the friction increases, the tire will heat up just like your hands did when you were rubbing them together.
Proper air pressure will help manage heat buildup. Too high air pressure will reduce the ability of the tire to deform and reduce the friction and traction.



Slides 33-36 – Inertia

Inertia is a property of matter that causes it to resist changes in velocity (speed and/or direction). According to Newton's first law of motion, an object with a given velocity maintains that velocity unless acted on by an external force. That external force could be wind, road friction, gravity or any combination of things. Inertia is the property of matter that makes this law hold true.

The amount of inertia that an object possesses is proportional to its mass. However inertia is not the same thing as momentum (the product of velocity and mass). The mass of an object can be measured by observing the extent of its inertia. This is done by measuring the amount of force required to produce certain acceleration such as getting an object moving, redirecting its path or stopping the object.

***Inertia* is a physics term. Sir Isaac Newton discovered that a body at rest would stay at rest and a body moving through space would continue moving through space unless an external force (like friction or gravity) caused it to slow down, stop, or change directions.**

Slide 34: Questions you may want to ask:

1. What are the forces that are holding the car on the road?

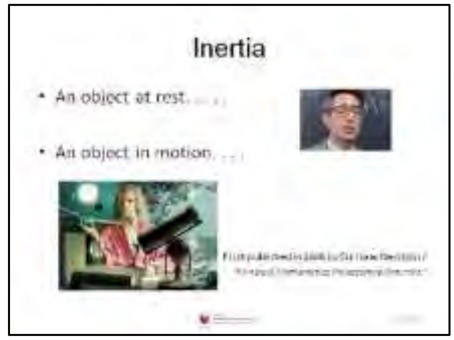
- **Answer—Friction of the road and the tires**
- **Answer—Low enough speed that the tires will not exceed the "coefficient of friction." If the speed is too fast the car will lose its ability to stay on the roadway as seen in the next slide.**

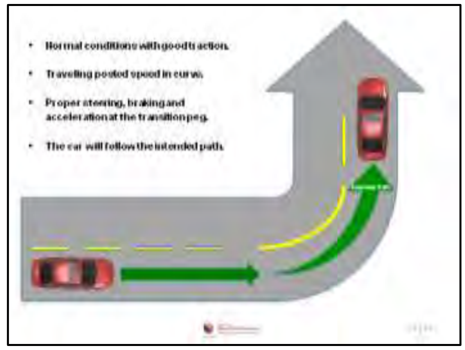
2. What happens to your body as the car goes around this corner? Why do you think that is?

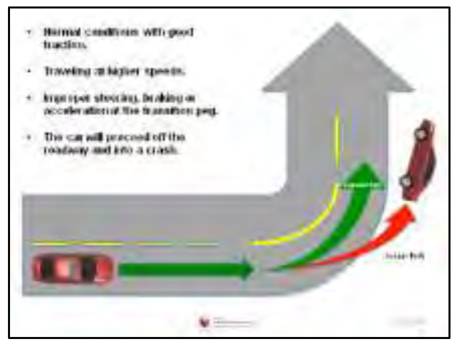
- **Answer—The body will continue ahead but the seat or door changes the direction you are going. It provides the force to redirect your energy.**

3. Knowing what you do about vehicle dynamics, what do you predict the car is doing at this time in terms of Yaw, Pitch, or Roll? What causes the car to respond that way?

- **Answer—The property of inertia will cause the car to continue straight ahead. The tires redirect the energy**







Mismanaged forces will cause the vehicle to take an unintended path and possibly roll over.

of the car to the new direction. Because the car is on a suspension and flexible tires, the car will roll to the right as it makes a left turn. If braking occurs the car will also pitch forward onto the front right tire.

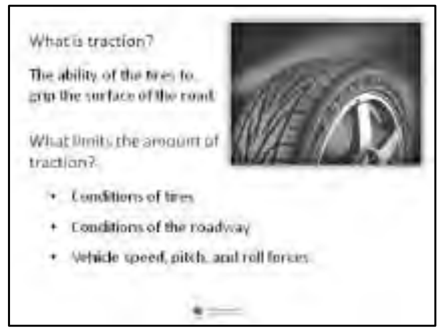
Slide 36 – Speed and loss of traction

Consequences of speed, loss of traction and a cliff. Gravity demands obedience. This car is designed for high speed maneuvering, but even it has its limits.

Slide 37 – What is Traction?

The ability of the tires to grip the surface of the road. What limits the amount of traction?

- **Conditions of tires**
- **Conditions of the roadway**
- **Vehicle speed, pitch, and roll forces**



Slide 38 – Tire tread

The tire on the right provides better traction especially in wet and snowy conditions. The deeper tread allows water to channel away from the road and the tire remains in contact with the roadway.

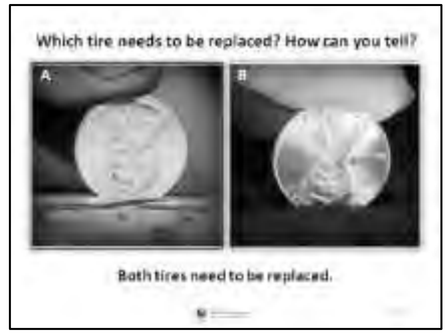
Slide 39 – Using a penny to check tire wear

How do I know when I need to replace my tires? When you put a penny in the tire tread, President Lincoln's head is completely exposed.

Slides 40-41 – Using a penny to check tire wear

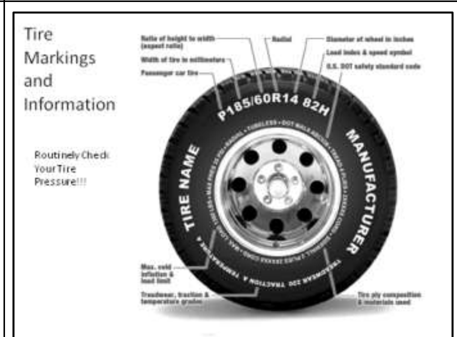
Time to replace this tire!

Both tires need to be replaced because President Lincoln's head is completely exposed.



Slide 42 – Tire markings and information

Where do you find maximum tire pressure?
Where do you find recommended tire pressure?
What is the difference?
Where you find maximum load information?
How do you check the tire pressure?



Slide 43 – PSI?

http://www.safercar.gov/ Promoting+Tire+Safety
Tire pressure monitoring systems (TPMS) measure *pounds per square inch* (PSI). TPMS will light up on dashboard when any tire is 25% under-inflated.

Which would have higher recommended tire pressure?

- **Racing Bicycle tires 65 – 110 PSI**
- **Mountain Bike tires 36- 44 PSI**
- **Tractor tires 14 – 22 PSI**
- **Car tires 33 - 35 PSI**

Criteria to calculate the right pressure:

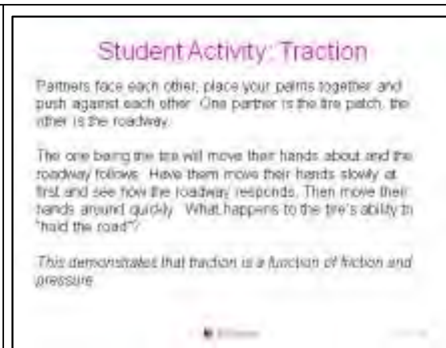
- **Size of tires**
- **Maximum speed**
- **Total weight supported by tires: machine weight +weight of tools + load transfer**

Slide 44 – Student Activity: Traction

Read slide for activity directions. An addition to this activity: you may want them to change the pressure on their hands together simulating what happens to traction when the vehicle goes over the crest of a hill and the car lifts a little.

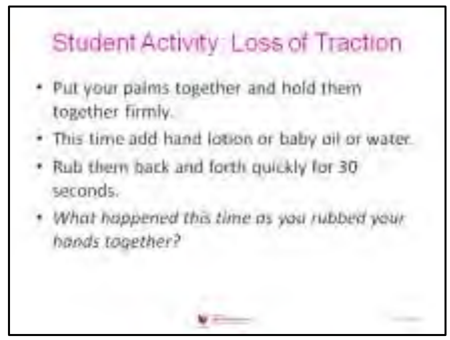
Refer to the friction activity where a foreign substance was added to the road such as oil or water. What do you predict will happen with the tires ability to "hold the road"?

Lighten the pressure and have them move their hands around. Explain what happens.



Slide 45 – Student Activity: Loss of Traction

Now we add the oil or lotion which simulates the presence of rain, snow or ice. They will notice how easy it is to move their hands and feel the loss of traction.



Slide 46 – Momentum in Winter

What happens to momentum in the winter? It stays the same. What happens to traction on a snowy road? It becomes less.

In order to manage the momentum in situations when the traction is less. the only way to do that is to SLOW DOWN!!!

However, sometimes when you are going up a hill it is important to use your momentum to keep you moving so you can crest the hill before you lose traction.

Slide 47 - Maximum Vehicle Load
Slide 48 - Vehicle Load Considerations

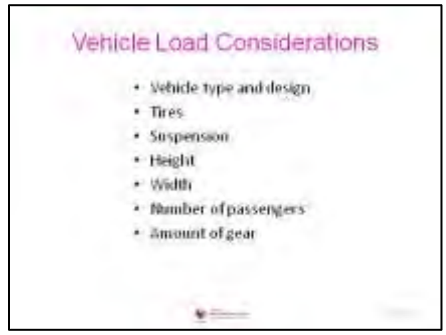
Vehicle type: Is it a truck, a passenger car, a Smart car? What kind of car is it and what is it designed to haul?

Tires: Are they passenger tires, truck tires, and are they rated to carry certain types of loads?

Suspension: Is it a truck or passenger suspension? Has the suspension been altered to "lift" the truck or lower it closer to the ground?

Height: Is it a tall vehicle with an even taller load or a short vehicle such as a sports car and how many seats does it have.

Width: Does it have a narrow or wide wheel base and how does that affect its handling?



Slide 49 – Exceeding Maximum Load

Every vehicle is designed to carry a maximum load. It is important to make sure you don't exceed the vehicle load because it drastically changes the handling characteristics of the vehicle. Why does that happen?

Slides 50- 52

The next three slides are examples of loads that probably exceed the maximum.

Slide 53 – Load and Balance **Center of gravity and vehicle load affects the driver's ability to manage vehicle balance, because as we increase vehicle load we also change the center of gravity.**	
Slide 54 – Height of the vehicle **Which vehicle has the highest center of gravity?** **How will that affect the vehicle balance when the vehicle goes around a corner? Describe it in terms of Yaw, Pitch, and Roll.**	
Slide 55 - Rollovers **Vehicle balance is more difficult in taller vehicles. This Range Rover has a higher center of mass and will roll more easily than the Toyota. Typically, you also see recreational equipment such as kayaks, canoes, and bicycles on racks above the SUV.**	
Slide 56 – Center of gravity **What will happen to the center of gravity when more gear is added to the top of a vehicle?** **What will happen if the driver takes a curve at the speed she normally does with the new higher center of gravity?**	

Slide 57 – Maximum load and center of gravity

This vehicle is exceeding maximum load and also has a much higher center of gravity.

What do you think the vehicle and its load will do if he swerves to avoid a car that slams on its brakes?

Slide 58 – Putting it all together

What can I do to work within Natural Laws to manage risk and drive more safely?

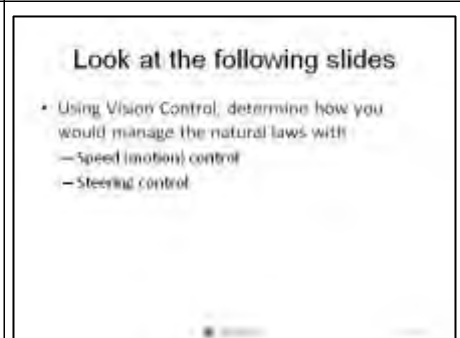
Slide 59 – Manage Natural Laws by …

Each of these items has a following slide to discuss what the driver needs to do to keep the car safely on the road and manage the forces if they are in a crash.

Slide 60 – Look at the following slides

The purpose of this activity is to put all the pieces together. The driver needs to understand that managing natural laws all starts with the ability to recognize that a change is occurring and that they need to take action to manage that change. The change can be snow, rain, frost, gravel, curve, hill, cars stopped, stop sign, etc.

Once the change is identified, then the driver needs to make some decisions. If the driver chooses not to take action or improperly identifies the appropriate change, they run the risk of mishandling the forces and possibly crashing their vehicle.



Slide 61 – Roundabout

Roundabout in nice weather.

Slide 62 – Roundabout

Here is the same roundabout in early winter. Notice that snow now changes the car's traction and ability to manage the forces created by the car going around the roundabout. If you look closely at the tire traction patterns, you will see that the rear tires are not in the front tire tracks and that the rear of the car is yawing out of the curve.

Questions you may wish to ask:

1. **How is this picture different than the one in the previous slide?**
2. **What changes have occurred that the driver needs to manage?**
3. **Describe what the driver needs to do with her vision as she gets ready to exit this curve?**
4. **How is this driver managing the forces and natural laws as she drives around this roundabout?**
5. **What did the driver do to cause the vehicle to begin to yaw?**
    - ***Too much speed in this part of the curve, slight downhill and negative camber on the curve will cause the car to yaw or early acceleration before the transition peg.***

Slide 63 – Vehicle Maintenance

Tires provide traction and the opportunity to turn, slow down, stop and accelerate.

Brakes wear over time and stopping becomes more difficult to slow and stop.

Fluid levels can change over time and if levels get low brake pressure decreases or disappears. Washer fluid in the window washer lets you clean the window in bad weather conditions.

Routine maintenance means taking care of your car on a regular basis. Checking fluid levels--oil, transmission fluid, power steering fluid, washer fluid, etc. and making sure the tires are inflated at their correct pressure are only a few of the things you need to do on a regular basis. You will also want to clean the windows inside and out and make sure your headlights are clear of road grime and dirt.

Remember, your car is the second largest purchase you will make in your life and you need to take care of it so it will last longer and be safer for your driving career.

Slide 64 – Occupant Protection

You can ask the students:

1. **What are the physics principles that contribute to the design of vehicles to protect occupants from serious injury or death in the event of a crash?**

2. **If a car is outfitted with airbags, is it necessary to buckle up? Explain.**

3. **What is a "backseat bullet?"**

Refer to Module 2.1 (slides 13 and 14) on the importance of buckling up, and Module 5.3 Protecting Occupants for a detailed overview of the natural laws governing the movement of vehicles and bodies in space, and how seat belts, child safety seats, air bags, and vehicle design combine to protect occupants in the event of a crash.

Slide 65 – You can't beat physics. Slow down!